CHAPTER 4. ENVIRONMENTAL CONSEQUENCES

Geology

Impacts to groundwater and local wells

Alternative A – No Action

The hydrologic patterns are greatly influenced by the geology of the area. Trout Creek runs along the margin of the older Ohanapacosh formation to the south and west and the younger Trout Creek Hill Basalts to the north and east (Fig. 3-1). The different flows from Trout Creek Hill have probably created confining layers that would separate aquifers in the area. Preliminary conclusions from a study conducted from 1983 through 1986 (Seesholtz 1986) show that Trout Creek can influence the recharge of the aquifer in the range of 2 to 4 cfs along a reach just above Hemlock Lake. These ranges are based on limited data and may not be indicative of long-range recharge, however it has been determined that groundwater levels in the area fluctuate as much as 60 feet over a year, with highs occurring in April or May and low levels in October or November. The groundwater level from the ground surface may also vary yearly based on the amount of precipitation. Wetter years will have higher levels from the surface and dryer years would lower measurable levels. Figure 4-1 indicates fluctuations in water levels at Observation Well #2 (Fig. 3-1, OW#2) over a 3-year period. (Seesholtz 1986.)

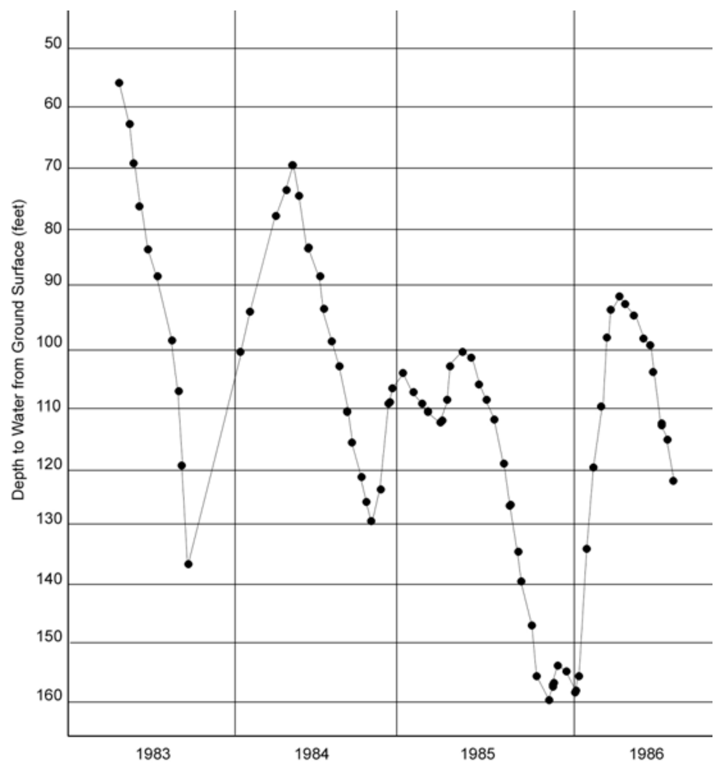

Figure 4-1. Depth to groundwater in OW#2 from 1983 to 1986. (Source: Seesholtz, 1986.)

The data indicate that there would be little difference in levels of groundwater between alternatives. Based on stream gauge readings comparing the stream flows above the lake and below the dam during a short time in August 1986, a net loss to the aquifer of between 2 and 4 cubic feet per second indicates that Hemlock Lake is only one of the sources providing recharge to the aquifer and that it's contribution is minimal. This analysis also supported by the fact that Trout Creek is about 12 miles in length and the length of the lake above the dam is about _ mile. Therefore the effect that the lake would have on groundwater recharge would be about 2% of the total for Trout Creek, as a whole, particularly for the area near the lower end of the Trout Creek system.

Alternatives B and C

Direct, Indirect and Cumulative Effects

Removal of the dam under Alternatives B and C would affect the aquifer very slightly but should little effect to the aquifer as a whole. There is not enough information to determine the amount of water that infiltrates the ground from the lake versus what amount would infiltrate if the dam did not impound the water behind it.

Alternatives D and E

Direct, Indirect and Cumulative Effects

Alternatives D and E call for leaving the dam in place. There should be negligible differences in the effects to the aquifer.

Soils

Soil Productivity – Within Standards and Guidelines

Alternative A – No Action

Wind River Nursery Development

Roads and constructed areas make up approximately six percent of the project area. The Wind River Nursery fields converted approximately 30 percent of the Soils Analysis Planning Area over to agriculture. Many of these fields are no longer managed for tree production, and some were recently conveyed to Skamania County.

Table 4-1. Approximate extent of development in Soils Analysis Planning Area (as shown in Figure 3-3).

Use	Acres	% of Total Area
Agriculture, nursery fields	152	30%
Buildings, structures	12	2%
Forest	294	59%
Recreation	10	2%
Roads[1]	19	4%
Hemlock reservoir	12	2%
Total	**500**	**100%**

[1] Approximately 6 meters average width given for all roads, paved or unpaved.

Soil compaction is an increase in soil bulk density, a decrease in soil porosity, or an increase in soil strength caused by application of mechanical forces such as weight and vibration. Soil displacement is the lateral movement of topsoil by mechanical forces such as equipment blades, vehicle traffic, or logs being yarded. Mixing of surface soil layers by disking, chopping, or bedding operation, are not considered displacement. Burial of soils by overlying soils or soil material is not considered displacement.

Roads and Infrastructure

Roads, parking areas and buildings convert the soil resource to a non-productive condition, and most of the precipitation that falls on compacted surfaces becomes surface runoff. Table 4-1 summarizes system road and building areas for the soils standards measure. Roads and constructed areas currently occupy approximately six percent of the project area. The values in Table 4-1 were estimated using Geographic Information Systems (GIS), and include roads within and adjacent to the project area boundary.

Recreation

Human activity in developed recreation sites can displace and compact soils. User-created trails have had a minor impact on the area around Hemlock Lake. An increase in visitors may result in a more of the recreation area impacted. Table 4-2 summarizes system trail lengths in the project area. National Forest system trails currently occupy approximately 0.1 to 0.3 percent of the project area. System trails were estimated using Geographic Information Systems (GIS), and include roads within and adjacent to the project area boundary. The picnic area is allocated in the Gifford Pinchot National Forest Plan as Management Area Category “2L” Developed Recreation. It occupies approximately 10 acres. Less than two acres of the area is currently developed for recreation at the picnic site.

Table 4-2. Recreational use developed areas

Trail Name	Acres
Trail 199	0.01
Trail PCT	0.46
Trail 59	0.25
Picnic Area	9.88

Contamination from Hemlock Dam Sediment

Alternative A – No Action

Existing Condition

Northwest Geotech (2002) evaluated the composition of the sediments in the reservoir and tested for the presence of contaminants. A Sediment Specialist for the Washington State Department of Ecology interpreted the report and concluded the sediments do not seem to “warrant special consideration for upland uses” (McMillan 2002). Greater than 90 percent of the sample solids were composed of sand sized grains.

Shallow probes of the sediment by a Forest Service Soil Scientist suggest that the sediment has relatively higher levels of organic matter considering the relatively darker colors normally associated with organic matter. It is likely that cobbles, boulders, and plant material such as trees, are buried in the sediments.

Approximately three and a half acres of the reservoir has vegetation growing on it. Ground based equipment may be able to travel on these bars, but significant rutting and soil damage could occur. Detrimental soil compaction is less likely to occur when ground equipment travels on these sandy bars.

Other Influences on Soil Resources

Alternative A – No Action

Existing Condition

In the project area, no areas of slope instability are designated with the Forest GIS layer that delineates riparian reserves. Field reviews did not detect any areas of slope instability or potential for instability.

Large scale fires burned through the nursery area in the early 1900s and in some parts, into the late 1920's (USDA 1996).

A considerable amount of species and habitat diversity for soil dwelling organisms exists in the wetland areas. No biological soil crusts were detected, and none are expected to be present in the activity area.

Hydrology

Stream flow

Alternative A – No Action

Existing Condition

Water levels and velocities change throughout the year at Hemlock Lake as a function of both natural discharge fluctuations in Trout Creek, and management of the flashboards on Hemlock Dam. During winter months, the flashboards are typically removed, or limited to just the outer edges of the dam (to force flows over the center of the dam crest). During the summer (typically beginning in June), the flashboards are installed across the dam crest, and the lake is backed up for summer recreational use. The flashboards increase the lake level by approximately four feet. Since closure of the Wind River Nursery, there have been no irrigation needs or other water withdrawals occurring at Hemlock Lake, therefore Trout Creek essentially passes directly through the lake, with minor additions of flow from direct tributaries to the lake, and losses to infiltration and evaporation.

Direct, Indirect and Cumulative Effects

Implementation of this Alternative would not change the existing hydrology or streamflow regimes in Trout Creek or the Wind River. The range of flow conditions experienced both upstream and downstream of the dam would not be altered except by natural changes and variations in streamflow. Inundation of various portions of the lake including the delta, islands, mud flats and wetlands would occur at similar frequencies and depths as are seen currently, as a result of both natural streamflow variations, and annual management of the dam flashboards.

Alternatives B and C

Implementation of Alternative B would remove the dam and allow the river to establish its own channel through what is now the lake. Removal of the dam would eliminate any water storage capacity now afforded in the lake area by the dam. This may result in slightly higher base flows during summer months due to reduced losses of water to evaporation and infiltration. Winter peak flows would not be significantly affected downstream of the dam.

Currently during both low and high flows, the dam functions as a run of river dam, in that water storage behind the dam is not manipulated on an event basis. The dam has no flood control capability. The only manipulation of storage volumes behind the dam is the seasonal installation and removal of the dam flashboards for summer recreational uses.

Since closure of the Wind River Nursery, there have been no water withdrawals from the lake. Consequently, during summer months the volume of streamflow entering the lake is generally equal to the volume flowing downstream past the dam with the exception of losses to evaporation and infiltration occurring in the lake. Water losses in the lake are not well quantified, but a comparison of discharge in Trout Creek upstream of the lake and downstream of the lake in the summer of 2004 showed a difference of just XX cfs in one day of monitoring.

In the winter, streamflow volumes entering the lake generally equal volumes leaving the lake, except during the rising limb of floods, when the river stage increases and allows inundation of greater areas behind the dam. As water spills out onto floodprone areas surrounding the lake, the volume of water storage is temporarily increased upstream of the dam. However, the storage that comes available through changes in flood stage is not large relative to the discharge volumes in Trout Creek during such events. Figure 4-2 compares the water storage capacity of Hemlock Lake with the storage available in Trout Creek in the absence of the dam under a range of flow conditions. This data was derived from HEC-RAS modeling of the current condition and projected conditions following dam removal (following Perkins and Barber, 1999).

Comparing water storage capacities with and without the dam in place indicates that without the dam, approximately 5 acre feet of water storage capacity are lost at a 2-year flood stage, and approximately 71 acre feet are lost at the 50-year flood stage. But when compared against the actual volume of water being discharged in Trout Creek during these events (Figure 4-3s), the storage losses become insignificant. For example, during a bankfull flood of approximately 2000 cubic feet per second, the water storage capacity of the lake (above the elevation of the dam crest) would be less than one percent of the water discharged during the flood. Similarly, for the 50-year flood, there are approximately 71 acre feet of storage essentially lost by removing the dam, and yet Trout Creek is discharging 421 acre feet per ***hour*** during such an event, quickly eclipsing any difference in storage.

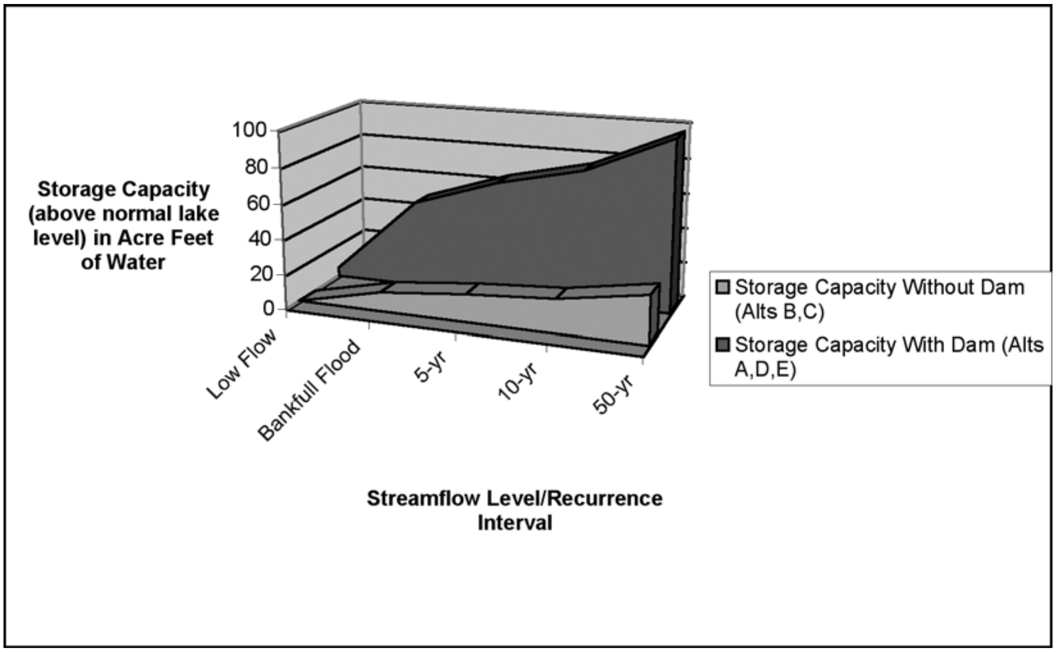

Figure 4-2. Water storage capacity (above normal lake level) at a range of streamflow levels and under both dam retention and dam removal scenarios.

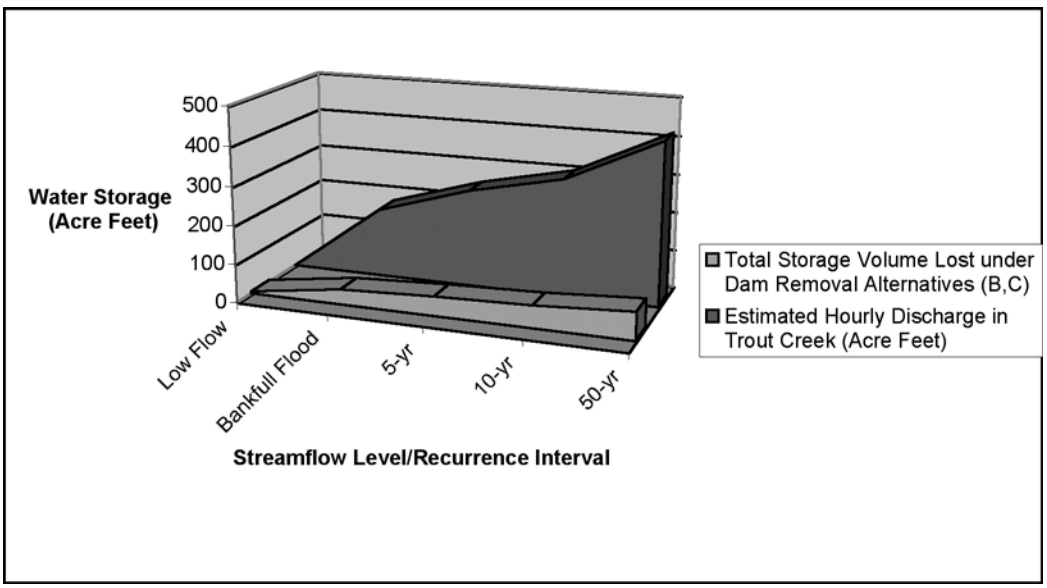

Figure 4-3. Comparison of the total volume of water storage lost under dam removal alternatives, with the hourly discharge volumes in Trout Creek under a range of streamflows.

Alternatives D and E

Effects of this Alternative would be identical to those described under Alternative A. Dredging of the lake would provide a deeper reservoir of water behind the dam, but neither low flows nor high flows would be affected.

Channels/Sediment

Existing Condition

Hemlock Lake has been in place for at least 70 years, since the construction of Hemlock Dam. Prior to the building of Hemlock Dam, there was an impoundment at the same location resulting (at least in part) from the presence of a splash dam, which was immediately upstream of the existing Hemlock Dam. Figure 4-4 is a photograph taken in 1912 showing the area now occupied by Hemlock Lake. At the time of the photo, the splash dam was in place, and the lower end of what is now Hemlock Lake, was inundated.

Figure 4-4. Hemlock Lake area in 1912. The splash dam can be seen at the lower end of the lake.

The lake has been filling with sediment since construction of Hemlock Dam. Concerns about the filling of the lake are found in anecdotal reports from as early as the 1950's (Misner letter to the USFS, 2004), and in Forest Service files from at least as early as 1970 (Thorn letter in June, 1970 to WW Gano in Appendix C of Seesholtz, 1986). In 1986, the Forest Service conducted a study of the "sedimentation" of Hemlock Lake, and proposed several alternatives for improving the recreational uses of the lake and its aesthetic values, primarily by dredging. Although the 1986 USFS report identifies "rapid buildup" of sediments in the lake, no documentation has been found as to whether this was perceived through ocular estimates or actually measured.

In the absence of any data describing the rate of filling of the lake, the Forest Service and Bureau of Reclamation have taken measurements and used data collected previously to assess the relative rates of sediment buildup in different parts of the lake.

Bathymetric surveys were conducted in 1994 for the purpose of evaluating reservoir storage and dredging options (Otak, 1994). In spring of 2004, additional elevation surveys were conducted by Mt Adams District personnel to compare sediment levels in the lake at that time with those of 1994. Although the 1994 survey was not replicated point-by-point in the 2004 survey, the results provide a general characterization of elevation changes occurring over the past decade in the lake and immediate vicinity. Figure 4-5 is an aerial view of the lake showing the average differences in surveyed elevations across the lake area.

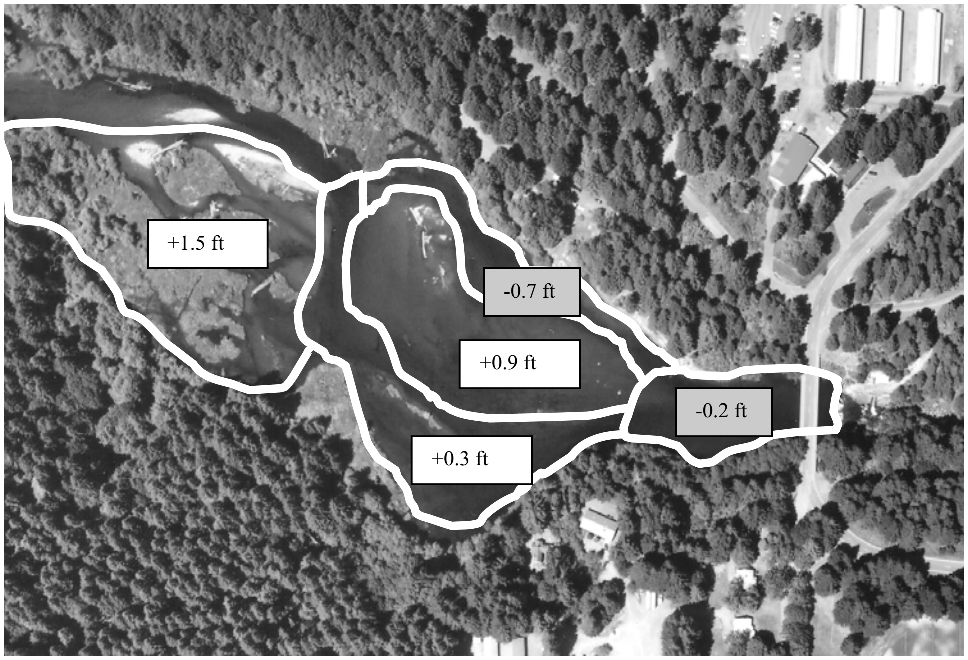

Figure 4-5. Aerial view of Hemlock Lake comparing average elevations measured in 1994 and 2004 surveys across different parts of the lake.

From this comparison, three of the five areas analyzed show an increase in average elevation over the ten-year period of time, averaging just under one foot of elevation. The other two areas show a decrease of approximately 0.5 feet, indicating that sediment levels in these areas have actually lowered over the ten-year interval.

Work done by the Bureau of Reclamation (BOR, 2004) provides an additional perspective on the growth of the bars and delta area. They analyzed photos of the lake for every decade since 1949, and found that the delta increased in aerial size by approximately 1.4 acres during that period (Figure 4-6).

Figure 4-6. Aerial photograph of Hemlock reservoir in 2000. The blue line is the delta in 1959; the red line is the delta in 2000.

Taken together, these analyses point to a continued accumulation of sediments in the lake over the past several decades, but also indicate that—at least for the past ten years—the magnitude of the changes is not dramatic. Within the time period analyzed, Trout Creek experienced a number of large floods, including one estimated to be the 100-year flood. Sediments in the lake would have been affected by other factors during this time as well. According to Seesholtz (1986), the Wind River Nursery used to flush sediments regularly through the sluice gate through approximately 1977, when the practice was curtailed. The volumes of material routed downstream in this way are unknown. Also, long time residents of the area recall an effort in the late 1950's in which sediments from the lower end of the lake were pushed up onto the island to help maintain depth in the lake (Misner, letter to the USFS, 2004). Although this effort probably would not have directly affected the amount of sediment within the lake, it did alter the location of the material, and in that way may have contributed to other adjustments in channel location and deposition of sediment and debris within the lake.

As a result of both natural variations in stream flows and intentional manipulation of the dam or sediments, it is likely that the lake has gone through periods of greater or lesser rates of filling and of scouring and routing sediment over the dam. Through this process, different parts of the lake are likely to have experienced accumulation or sediment loss based on the alignment of the main channel as it transits the lake. Currently, it appears that the large bar in the middle of the lake has grown in elevation and in areal size, and may be pinching the southern channel further to the south.

Sediment Characteristics—Hemlock Lake

In 2001, the Forest Service commissioned a study of the sediments within the lake, to assess both the volume of material and quality of the sediments. This study manually probed the depths of sediment throughout the lake, and submitted 9 composite samples from across the lake and at depths within the lake for laboratory analysis. The study concluded that there were approximately 61,800 cubic yards of sediment within the lake, but acknowledged that the estimate could be low as a result of the size of substrate in parts of the lake, and the fact that the manual probe may have met refusal before reaching the bottom of the sediment. Substrates within the lake were found to be primarily coarse-grained materials consisting of sand and gravel-sized particles, with the percentage of fines ranging from about 3 to 9 percent. Table 4-3 summarizes the results of the particle size analysis. A more complete description of the sediment quality is included in the Soils section of this statement.

Table 4-3. Representative diameters measured from sediment samples in Hemlock reservoir.

Sample Number	d10 (mm)	d50 (mm)	d90 (mm)
A-1	0.07	0.30	1.5
A-2	0.08	0.45	3.5
A-3	0.19	0.85	4.0
A-4	0.09	0.40	2.8
A-5	0.15	0.92	4.2
A-6	0.09	0.75	3.5
A-7	0.20	0.80	4.0
A-8	0.08	0.50	3.0
Average	**0.12**	**0.62**	**3.31**

The Bureau of Reclamation used the results of the NW Geotech study along with stream elevations upstream and downstream of the dam, to project a total sediment volume within the lake and delta (BOR, 2004). Estimated sediment deposition within the lake and delta ranged from 48,000 cubic yards to 93,000 cubic yards (Table 4-4).

Table 4-4. Summary of estimated sediment volumes and composition. (Source: BOR, 2004 and NW Geotech, 2002.)

	Lower Estimate (yd^3)	Upper Estimate (yd^3)	Composition
Reservoir Pool	41,000	82,000	Sand, d_{50} = 0.6 mm
Delta	6,700	11,000	Sand and gravel
Total	48,000	93,000	

Sediment Characteristics—Trout Creek

Upstream of Hemlock Dam the bed material is largely gravel and cobble (see Table 4-5 for definition of sediment classes). Downstream of Hemlock Dam, Trout Creek enters a canyon and the bed is composed of large boulders and bedrock. Gravel is only found on the margins of the channel. This supports the conclusions drawn in the previous section, that the channel downstream of Hemlock Dam is supply limited and has a much large transport potential than the channel upstream of the dam.

The bed material gradation upstream of the dam was estimated using a photograph of an exposed bar. The flow rate at the time of the photograph was near 100 cfs and therefore much of the channel was exposed. The particles were digitized and the intermediate axis was used to estimate the particle diameter. The computed gradation is given in Figure 4-7. The median particle diameter (d_{50}) of this sample was 60 mm.

Table 4-5. Definition of Particles Sizes for Sediment Analyses.

Sediment Type	Size Class	Size range (mm)
Fines	clay	0.00024 – 0.004
	silt	0.004 – 0.062
Coarse	sand	0.062 – 2
	gravel	2 – 64
	cobble	64 – 256
	boulder	256 – 4096

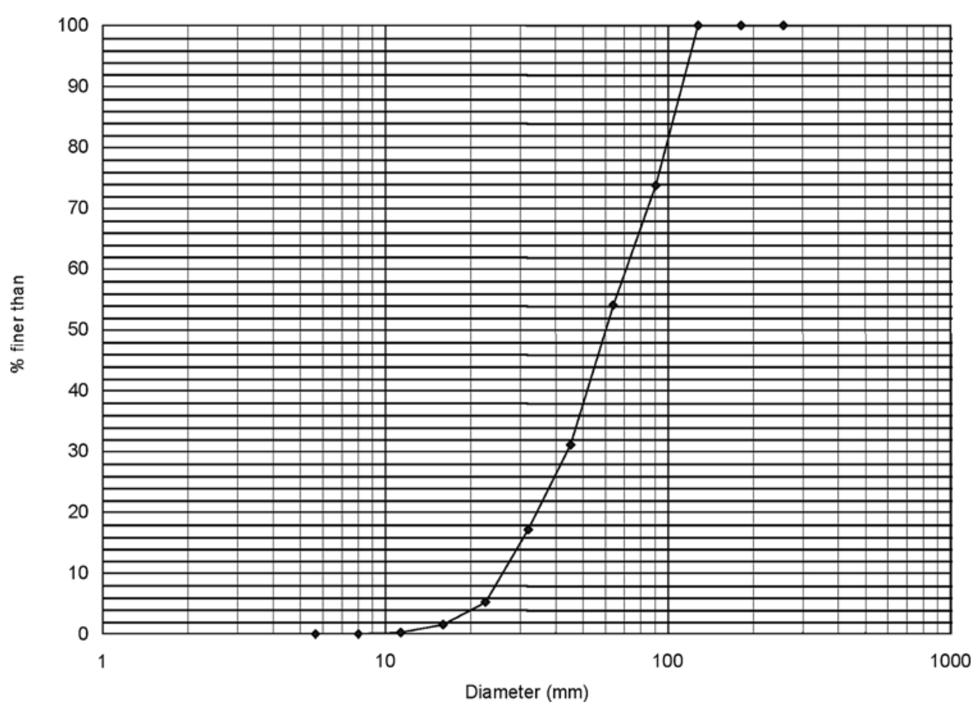

Figure 4-7. Bed material size gradation upstream of Hemlock Dam on Trout Creek. Estimated from photograph of point bar (BOR 2004).

Sediment Transport

The longitudinal profiles of both Trout Creek and the Wind River are shown in Figure 4-8, along with the QS product (2-yr flood peaks and stream slope). The QS product is an indicator of the power available for sediment transport (BOR 2004). Reaches with a low QS product cannot transport as much sediment as reaches with higher QS products. (*ibid.*)

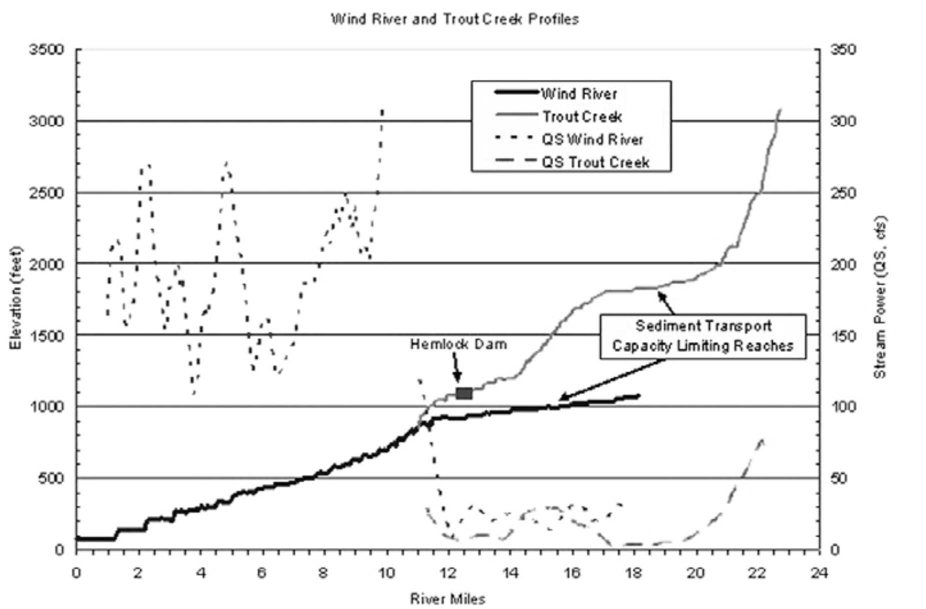

Figure 4-8. Stream profile and stream power in Wind River and Trout Creek (BOR 2004).

On Trout Creek, QS products increase sharply just below the dam, indicating that reaches downstream of the dam are capable of transporting more sediment than the reaches immediately upstream. Similarly, the QS products for the Wind River near the mouth of Trout Creek increase in a downstream direction, and are significantly higher than Trout Creek once the two streams join. The calculated QS products along with the lack of stored sediment and dominance of bedrock in the downstream reaches of Trout Creek (Figure 4-9) and in the Wind River (Figure 4-10) indicate that these reaches are sediment supply-limited, meaning that they are capable of moving more sediment than is currently being delivered to them.

Figure 4-9. Boulder-dominated reach of Trout Creek, approximately 0.5 miles downstream of Hemlock Dam.

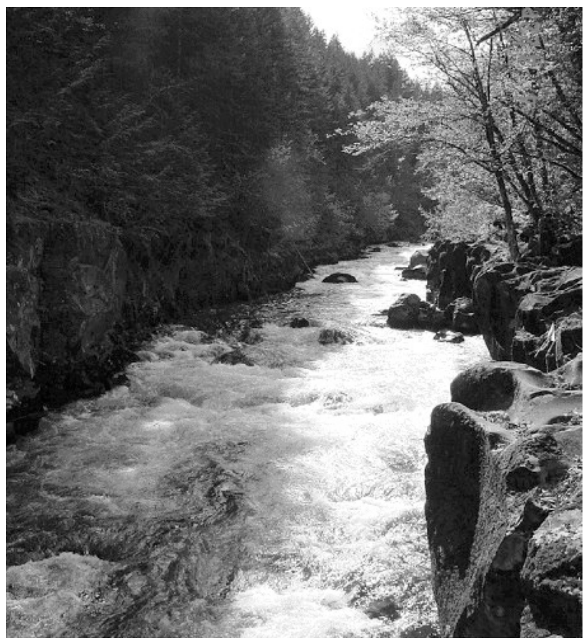

Figure 4-10. Bedrock-controlled reach on the Wind River, approximately _ mile downstream of the confluence with Trout Creek.

To estimate the sediment transport characteristics in Trout Creek the hydraulic properties were first estimated assuming normal depth the stream characteristics as given in XX. In addition, the bank slopes were assumed 2H:1V, the Manning's roughness coefficient was set to 0.035; the width to depth ratio was assumed 25. The computed hydraulic properties upstream and downstream of Hemlock Dam are shown in Table 4-6 and Table 4-7, respectively.

An important result of the above analysis is that it shows that bed upstream of Hemlock dam is not often mobilized. The d_{50} (the diameter at which 50% of the sediment is finer than) of the bed material upstream of Hemlock Dam is approximately 60 mm. This size is only mobilized if the flow is greater than approximately 3,000 cfs, which is between the 5 to 10-yr floods. Downstream of Hemlock dam, much larger material is mobilized more frequently.

The critical diameter for suspended load is defined as the diameter below which the sediment moves purely as suspended load. Suspended sediment transport rates are much greater than bed load sediment transport rates. Downstream of Hemlock Dam, particles as large as 3.5 mm travel as pure suspended load during the 2-yr flood (2,000 cfs). The d_{90} of the reservoir sediments is approximately 3.3 mm and therefore over 90% of the reservoir material will travel as suspended load at such flows.

The transport potential for various sized sediment at various flows is given in Table 4-6 and Table 4-7. In agreement with the previous analyses, the transport potential downstream of Hemlock Dam is much larger than upstream of the dam.

No measurements of sediment load or concentrations in Trout Creek or the Wind River have been documented. Therefore, the annual sediment loads in the basin are uncertain. Using studies from other areas of the western Cascades in the Pacific Northwest, we can estimate that sediment loads in the Wind River watershed would be on the order of

Table 4-6. Hydraulic properties and sediment transport capacity *upstream* of Hemlock Dam (Assuming a minimum slope = 0.004), 'Yang' refers to the transport formula of Yang (1973) and MPM refers to the transport formula of Meyer-Peter-Muller.

							Potential Transport		
Depth	Flow Rate	Velocity	Top Width	Fraction Flow Less than	Critical Motion Dia	Critical Suspension Dia	Dia = 0.6 mm (Yang)	Dia = 16 mm (MPM)	Dia = 60 mm (MPM)
(feet)	(ft^3/s)	(ft/s)	(feet)	(-)	(mm)	(mm)	(mg/l)	(mg/l)	(mg/l)
0.36	4	1.27	9.0	0.000	5	0.1	500	0	0
0.5	9	1.58	12.5	0.040	7	0.2	800	0	0
0.6	15	1.78	15.0	0.127	9	0.2	1,000	0	0
0.7	22	1.98	17.5	0.192	10	0.3	1,200	0	0
0.8	32	2.16	20.0	0.229	11	0.3	1,400	0	0
0.9	44	2.34	22.5	0.276	13	0.3	1,600	0	0
1.0	58	2.51	25.0	0.318	14	0.4	1,800	0	0
1.1	74	2.67	27.5	0.354	16	0.4	1,900	0	0
1.2	94	2.83	30.0	0.404	17	0.5	2,100	0	0
1.3	116	2.99	32.5	0.470	18	0.5	2,200	0	0
1.4	142	3.14	35.0	0.513	20	0.5	2,400	0	0
1.5	170	3.29	37.5	0.562	21	0.6	2,500	0	0
1.7	238	3.57	42.5	0.660	24	0.7	2,800	200	0
2.0	366	3.98	50.0	0.828	28	0.8	3,200	500	0
2.2	472	4.24	55.0	0.896	31	0.8	3,400	700	0
2.4	596	4.50	60.0	0.936	34	0.9	3,700	900	0
2.6	737	4.74	65.0	0.959	37	1.0	3,900	1,100	0
2.8	899	4.98	70.0	0.971	40	1.1	4,100	1,200	0
3.0	1,080	5.22	75.0	0.980	43	1.2	4,300	1,300	0
3.5	1,629	5.78	87.5	0.993	50	1.3	4,800	1,500	0
4.0	2,326	6.32	100.0	1.000	57	1.5	5,200	1,700	0
4.5	3,185	6.84	112.5	1.000	64	1.7	5,600	1,800	0
5.0	4,218	7.34	125.0	1.000	71	1.9	6,000	1,900	0
5.5	5,438	7.82	137.5	1.000	78	2.1	6,400	2,000	0
6.0	6,858	8.28	150.0	1.000	85	2.3	6,700	2,100	100
Total Annual Transport Potential Using Flow Duration Curve (yd^3/yr)							**540,000**	**110,000**	**0**

Table 4-10. Hydraulic properties and sediment transport capacity *downstream* of Hemlock Dam (Assuming a minimum slope = 0.01).

							Potential Transport		
Depth	Flow Rate	Velocity	Top Width	Fraction Flow Less than	Critical Motion Dia	Critical Suspension Dia	Dia = 0.6 mm (Yang)	Dia = 16 mm (MPM)	Dia = 60 mm (MPM)
(feet)	(ft^3/s)	(ft/s)	(feet)	(-)	(mm)	(mm)	(mg/l)	(mg/l)	(mg/l)
0.36	5	2.04	7.2	0.000	13	0.4	3,600	0	0
0.5	11	2.54	10.0	0.079	18	0.5	4,900	0	0
0.6	19	2.87	12.0	0.162	22	0.6	5,800	200	0
0.7	28	3.18	14.0	0.221	26	0.7	6,500	1,000	0
0.8	40	3.47	16.0	0.255	30	0.8	7,300	1,900	0
0.9	55	3.75	18.0	0.311	33	0.9	7,900	2,600	0
1.0	72	4.03	20.0	0.353	37	1.0	8,600	3,200	0
1.1	93	4.29	22.0	0.404	41	1.1	9,200	3,700	0
1.2	118	4.55	24.0	0.473	44	1.2	9,700	4,200	0
1.3	146	4.80	26.0	0.521	48	1.3	10,300	4,600	0
1.4	178	5.04	28.0	0.568	52	1.4	10,800	4,900	0
1.5	214	5.28	30.0	0.625	55	1.5	11,300	5,100	0
1.7	298	5.74	34.0	0.754	63	1.7	12,200	5,600	0
2.0	460	6.39	40.0	0.890	74	2.0	13,400	6,100	0
2.2	594	6.81	44.0	0.936	81	2.2	14,200	6,300	100
2.4	749	7.22	48.0	0.959	89	2.4	14,900	6,500	400
2.6	927	7.62	52.0	0.974	96	2.6	15,600	6,600	800
2.8	1,129	8.00	56.0	0.983	103	2.8	16,300	6,700	1,200
3.0	1,357	8.38	60.0	0.991	111	3.0	16,900	6,800	1,500
3.5	2,047	9.28	70.0	0.997	129	3.5	18,300	7,000	2,300
4.0	2,923	10.15	80.0	1.000	148	4.0	19,600	7,000	2,900
4.5	4,002	10.98	90.0	1.000	166	4.5	20,800	7,100	3,400
5.0	5,300	11.78	100.0	1.000	185	5.0	21,800	7,100	3,700
5.5	6,833	12.55	110.0	1.000	203	5.5	22,800	7,100	4,100
6.0	8,618	13.30	120.0	1.000	222	6.0	23,700	7,100	4,300
Total Annual Transport Potential Using Flow Duration Curve (yd^3/yr)							**2,100,000**	**910,000**	**54,000**

Alternative A – No Action

Direct, Indirect and Cumulative Effects

Implementing this Alternative would have no immediate effect on the current processes or conditions in the lake or in Trout Creek upstream and downstream of the lake. Riparian vegetation would continue to develop around the lake, and continue to colonize and stabilize the upper delta area. Cycles of sediment deposition and movement through the lake would continue to occur as they have in the past with a general trend toward increasing sediment levels and expansion of the bars and delta.

In evaluation of sediment deposition rates in Hemlock Lake, the BOR report found that the reservoir itself is in a state of equilibrium, meaning that sands and silts entering the reservoir are largely routed over the dam (BOR 2004). In the same analysis, they found that the delta has grown by approximately 1.4 acres over the past 50 years. Assuming an average thickness of 3 to

5 feet, this would equate to deposition of approximately 6,700 to 11,000 yards of material in the delta during the period of 1949-2000, or 130 to 220 cubic yards of material per year. Projecting that growth rate forward, the report estimated that the delta would continue to grow and reach the dam crest in approximately 240 years, barring "extreme changes in the watershed or climate." (*ibid.*)

Alternative B

Direct, Indirect and Cumulative Effects

This alternative would remove the dam and allow river processes to create a new channel through the area now covered by Hemlock Lake. A pilot channel excavated into the existing lakebed would direct development of the new channel to what is presumed to be the location of the historic (pre-dam) channel (Figure 4-11). The purpose of this pilot channel would be to reduce the total volume of sediment eroded from the lake by shortening the process in which the channel would find its historical alignment. During the initial period following removal of the dam, the channel would be expected to incise rapidly through the lake sediments.

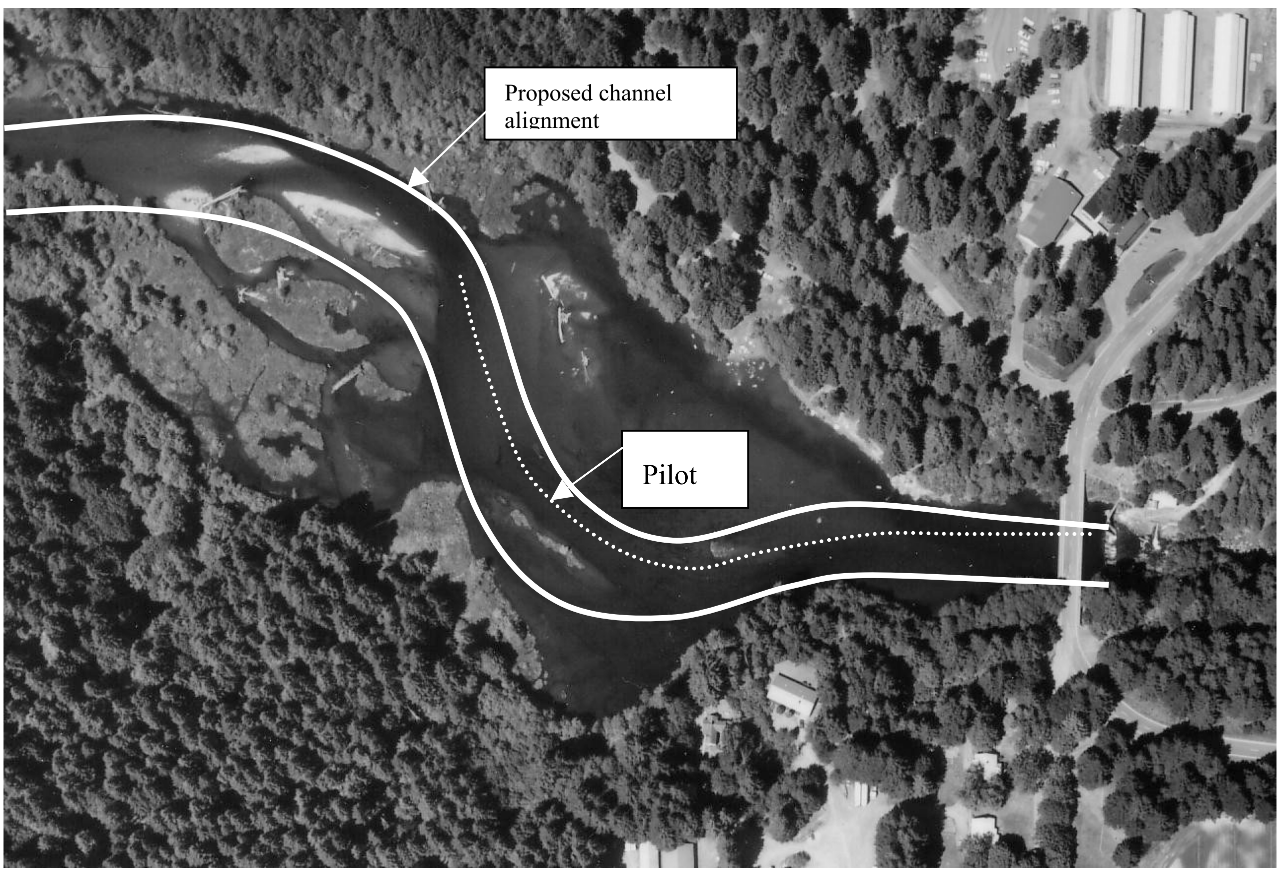

Figure 4-11. Proposed channel alignment and location of the pilot channel.

The release of sediment to the downstream river channel will cause three major impacts: 1. A temporary rise in suspended sediment concentrations, 2. A temporary increase in river bed elevations immediately downstream of Hemlock Dam, and 3. Deposition of sediment near the mouth of the Wind River. The qualitative and quantitative description of these impacts follows.

Reservoir Erosion

The most important factor in determining the downstream impacts is the rate and volume of sediment erosion from the reservoir. Under Alternative B1, sediments will be allowed to erode naturally from the reservoir area. Before the dam is removed, the sluice gate will be opened and sediments will be eroded from the reservoir and travel downstream. The concentrations will be extremely high as compared to background concentrations. It is assumed that the sluicing will be performed during the low flows of August, when the average flow is slightly less than 20 cfs. This flow will erode a channel slightly more than 10 feet wide at its base. The side slopes of the channel are uncertain, but could be quite steep. A side slope of 1H: 1V is a mean estimate. Approximately 7,000 to 14,000 yd^3 of material could be sluiced out at a flow of 20 cfs and it would take 20 to 40 days to accomplish this flow. Larger flows would cause additional erosion and cause the process to occur more quickly.

After the dam is completely removed, which is expected to occur before the flows begin to increase again in late September or early October, higher flows may erode larger channels through the sediment. Only flows that are the larger than any other flow since dam removal will erode significant amounts of sediment from behind the dam. The total volume of sediment eroded is dependent upon the pre-dam profile and there are no reliable estimates of the pre-dam profile. Some estimates of the pre-dam profile are given in Figure 4-12. The best estimate of the pre-dam slope in the reservoir area is between 1.5 % and 1.9 %. The length of sediment deposition is approximately 1500 feet for the pre-dam slope of 1.5% and 1000 for the pre-dam slope of 1.9 %. The estimated total eroded volume for the two cases are 61,000 yd^3 for the 1.5 % slope and 38,000 yd^3 for the 1.9% slope. These two volume estimates are assumed to bracket the range of potential eroded sediment volumes. Using the annual estimated sediment load at the mouth of the Wind River of 13,000 yd^3/yr, the amount of sediment eroded from behind Hemlock Dam is between 4.7 to 2.9 times greater than the annual sediment supply of Wind River.

Once the channel has reached a grade and location that is relatively stable over time, the channel banks would likely continue to remain oversteepened while erosion, freeze/thaw activity, and mechanical forces work to bring the channel banks back to a more stable angle of repose. The persistence of these oversteepened conditions would be a function of the cohesiveness of the lake sediments, the levels of disturbance on those slopes by hydraulic forces or by human and animal traffic, and weather conditions.

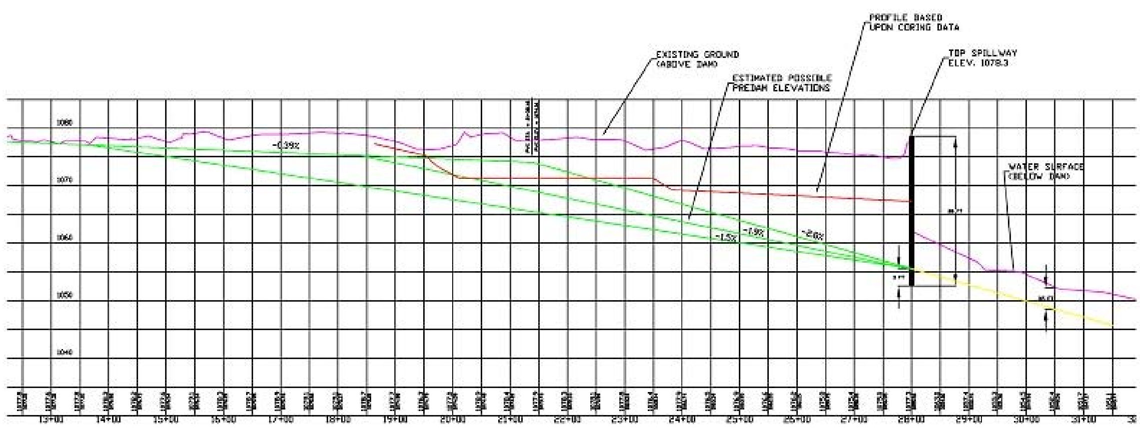

Figure 4-12. Estimates of the pre-dam profile of Trout Creek in the Hemlock Lake reach (BOR 2004, USFS unpublished data 2004).

Sediment from the incising stream would quickly move into the downstream reaches of Trout Creek. Due to the high stream power in these reaches of Trout Creek and the Wind River, particles as large as 3.5 mm travel as pure suspended load during the 2-year (2,000 cfs) flood (BOR 2004). Approximately 90% of the sediments within Hemlock Lake are 3.3 mm or smaller (NW Geotech), so over 90% of the reservoir material would travel at suspended load under bankfull flow conditions.

Deposition

Some deposition will occur downstream of the dam. Because of the high energy of the flow and low upstream supply, the deposition will be of small magnitude and will be temporary. To quantify the impacts, a simple aggradation model described by Greimann (BOR 2004) was used. The hydrograph scenario that was used in the model was based on the measured hydrograph of the 1996 flood, which was the flood of record on Trout Creek, and estimated to be the 100-yr or greater flood. A flow of 20 cfs was assumed to occur for 30 days, followed by a flow of 2000 cfs for 2 days, followed by a flow of 6000 cfs for 1 day.

Two different bed profiles were modeled. One assumed a channel slope of 1.5% through the lake reach following dam removal, and the other assumed a channel slope of 1.9 %. The length of channel eroded in the model was approximately 1500 feet for the channel slope of 1.5% and 1000 feet for the channel slope of 1.9 %. The profiles are shown in Figure 4-12. The estimated total eroded volume for the two cases are 61,000 yd^3 for the 1.5 % slope and 38,000 yd^3 for the 1.9% slope. These two volume estimates are assumed to bracket the range of potential eroded volumes.

The results for the maximum eroded volume case (channel slope of 1.5%) are shown in Figure 4-13 to 4-16. Figure 4-13 (1^{st} of 4) shows the downstream deposition during the 20 cfs flow. Figure 4-14 (2^{nd} of 4) shows the deposition during the 2000 cfs flow, which is assumed to follow the 20 cfs flow. Figure 4-15 shows the deposition during the 6000 cfs flow. The deposition wave for the 2000 cfs flow moves through Trout Creek in a period of approximately 2 days. During the 6000 cfs flow, the deposition wave moves through Trout Creek in approximately _ day.

In May, 2004, the BOR conducted a site visit and followup analysis to address concerns raised by a landowner who owns a residence on Trout Creek approximately _ mile downstream of the dam. The following summarizes the results of this analysis.

> The maximum deposition expected at a point 0.5 miles downstream of the dam is approximately 0.5 feet during the 100-yr flood. Results are also shown for the minimum eroded sediment volume (pre-dam slope of 1.9 %). The deposition at a point 0.5 mile downstream is estimated to be approximately 0.25 feet for the case of the minimum eroded sediment volume.
>
> The associated rise in flood elevations would be less than the amount of deposition. The maximum rise in the 100-yr flood elevations rise will be less than 6 inches and will be temporary. A 6-inch rise in water surface is relatively difficult to measure and is not considered significant. In addition, the 6-inch rise would occur only if the 100-yr flood is the first flood to occur after dam removal. If, for example, several 2-yr storms occurred or one 10-yr storm occurred before the 100-yr flood arrives, the rise in the 100-yr flood elevations would be much less than 6 inches. Therefore, the impact of Hemlock Dam removal on flood elevations is not considered significant.

After Trout Creek enters the Wind River, the transport potential increases tremendously. A plot of the estimated stream power is given in Figure 4-16. Because of the large increase in stream power, the deposition values given in Figures 4-13 to 4-16 will be further diminished in the Wind River. It is expected that deposition will only be measurable in the channel margins, pools and slack water areas. It is possible that sediment is temporarily stored in these locations.

No detailed survey of the Wind River is available, so it is not possible to perform a detailed computation of the volume of these areas. However, rough estimates of the approximate available storage volumes are found in Table 4-11. The volume of available storage in the Wind River was divided into two categories: Channel Bed Storage and Eddy Storage. Channel Bed Storage includes the storage areas on the margins of the channel. Eddy Storage includes those areas behind large boulders and will include the pool volume those large boulders create. The estimates for the total available area for storage vary between 350 yd^3 and 16,000 yd^3. These volumes can be compared to the estimated volume of reservoir erosion of between 38,000 yd^3 and 61,000 yd^3. If 16,000 yd^3 is temporarily stored in the Wind River, some pools and slack water areas may be temporarily filled with sediment. In particular, during the first low flow of around 20 cfs, the pools downstream of Hemlock Dam on Trout Creek could all be filled with fine sediment. Once the sediment enters the Wind River, because of the large dilution the deposition in the pools is expected to be much less. As soon as the first larger flows occur (200 cfs or greater) the pools will start to erode. It is expected that after a flood as large as the 2-yr flood, the pools will return to their normal condition. Based on the data of Wohl and Cenderelli (2000), the pools were restored to their normal condition after flows of no more than 440 cfs.

At the mouth of the Wind River, the slope decreases dramatically and the transport potential has a corresponding decrease. Based upon bathymetric survey, the area of the mouth of the Wind River is 37 acres and the average depth is 6 feet. It is estimated that practically all the sediment eroded from behind Hemlock Dam will eventually reach the mouth of the Wind River. However, some of the finer sediment will pass through and enter the Columbia. Based on the ratio of fall velocity to shear velocity and the median size of sediments within Hemlock Lake, it is estimated that approximately _ of the sediment eroded from Hemlock Reservoir would deposit at the mouth of the Wind River upstream of the Highway 14 Bridge. If the deposited volume is spread uniformly over the mouth of the Wind River, the depth will be between 2 to 3 inches. It would be difficult to measure a deposition thickness this small. Actual deposition patterns within the mouth would be highly variable, depending on the depth and slope of the river, the backwater influence, and the location of flow obstructions.

Table 4-11. Approximate storage volumes in the Wind River.

Channel Bed Storage	**Low Est.**	**Mid. Est.**	**High Est.**
River length (mi)	12	12	12
River width (feet)	50	60	70
Percent storage area	1%	2.5%	5%
Storage thickness (ft)	0.1	0.25	0.5
Storage Volume (yd^3)	120	880	4,100
Eddy Storage	**Low Est.**	**Mid. Est.**	**High Est.**
Percent channel length	10%	25%	50%
Storage length (mi)	1.2	3	6
Storage width (ft)	2	3	5
Storage thickness (ft)	0.5	1	2
Storage Volume (yd^3)	240	1,760	12,000
Combined Storage (yd^3)	**360**	**2,640**	**16,000**

Table 4-12. Fraction of reservoir sediments that will be suspended as a function of flow and location upstream of Hemlock Dam.

Distance from Dam (ft)	Max Depth of Sediments (ft)	Suspended Fraction		
		20 cfs	2000 cfs	6000 cfs
0	0.0	0.00	0.25	0.25
100	1.3	0.00	0.25	0.25
200	2.7	0.00	0.25	0.25
300	4.0	0.00	0.25	0.25
400	5.3	0.25	0.50	0.50
500	6.7	0.25	0.50	0.50
600	8.0	0.50	0.90	0.90
700	9.3	0.50	0.90	0.90
800	10.7	0.50	0.90	0.90
900	12.0	0.50	0.90	0.90
1000	13.3	0.50	0.90	0.90
1100	14.7	0.50	0.90	0.90
1200	16.0	0.50	0.90	0.90
1300	17.3	0.50	0.90	0.90
1400	18.7	0.50	0.90	0.90
1500	20	0.50	0.90	0.90

Table 4-13. Summary of results from downstream sediment transport model

Flow (cfs)	20	2000	6000
d_{50} of mobilized bed load (mm)	1	16	16
Average Downstream Concentration (mg/l)	4500	7000	7100
Eroded Width (ft)	11	52	32
Total Width (ft)	11	63	95
Eroded Volume – Min (yd^3)	7,000	19,000	12,000
Eroded Volume – Max (yd^3)	14,000	29,000	18,000

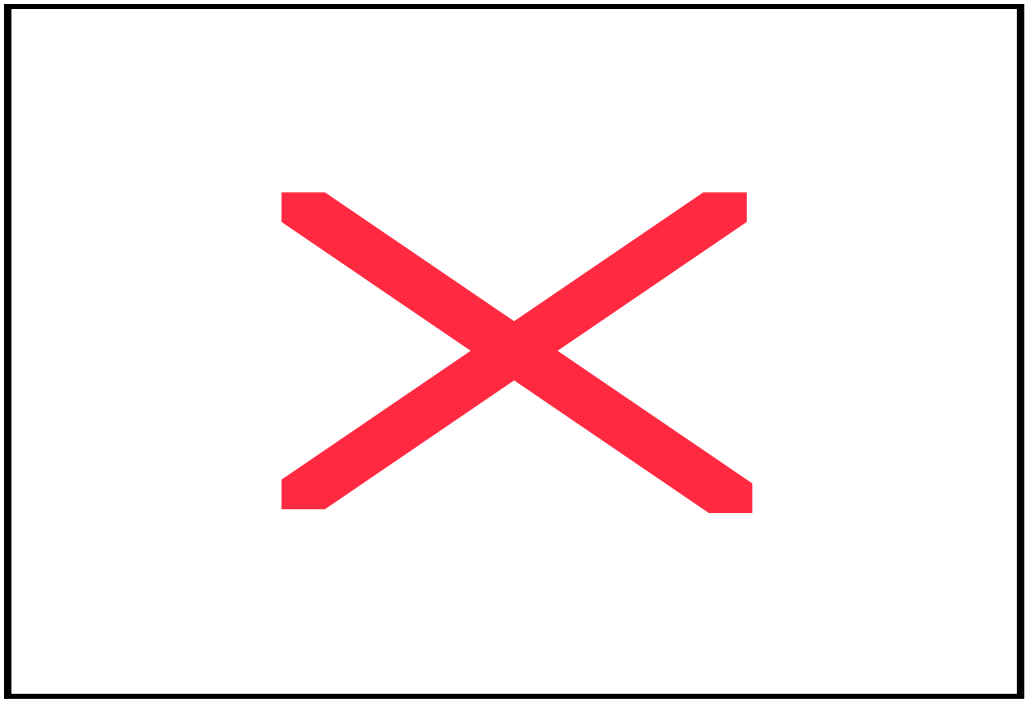

Figure 4-13. Fraction of reservoir sediments that will be suspended as a function of flow and location upstream of Hemlock Dam.

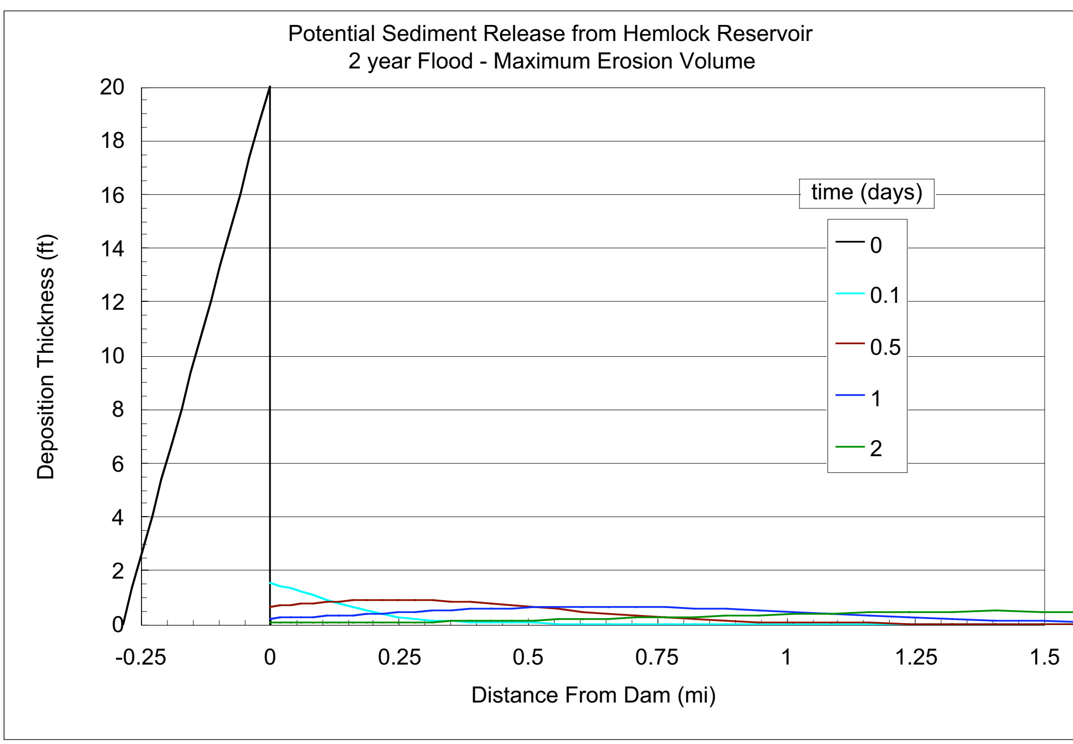

Figure 4-14. Deposition downstream of Hemlock Dam for 2-year flood following dam removal.

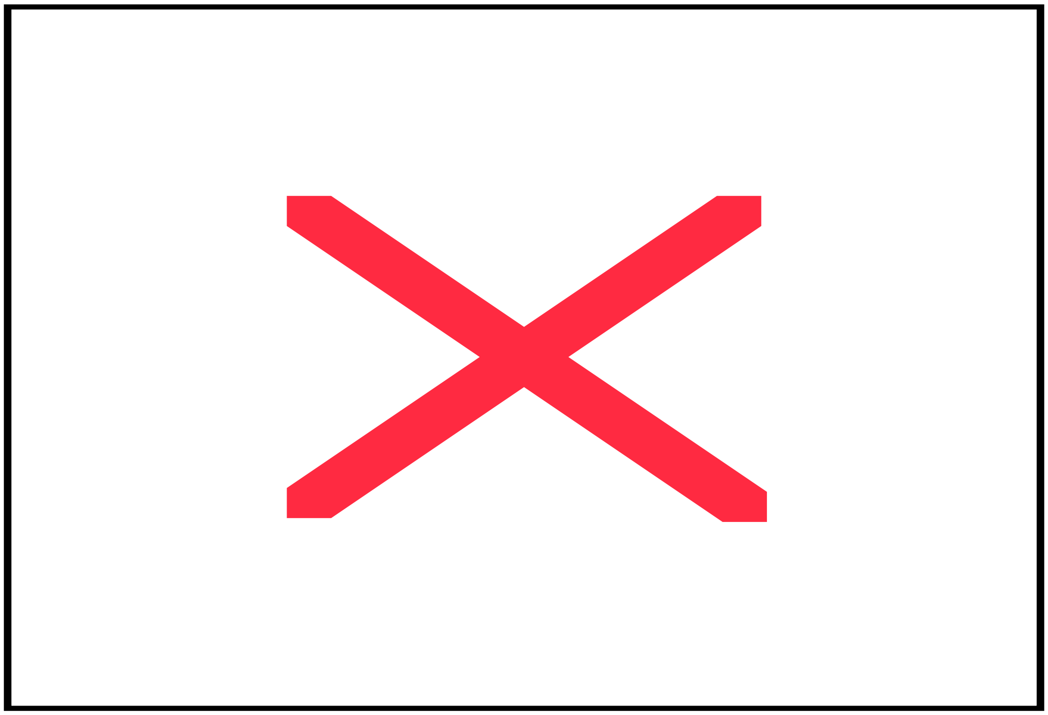

Figure 4-15. Deposition Downstream of Hemlock Dam for 100-year Flood Following Dam Removal.

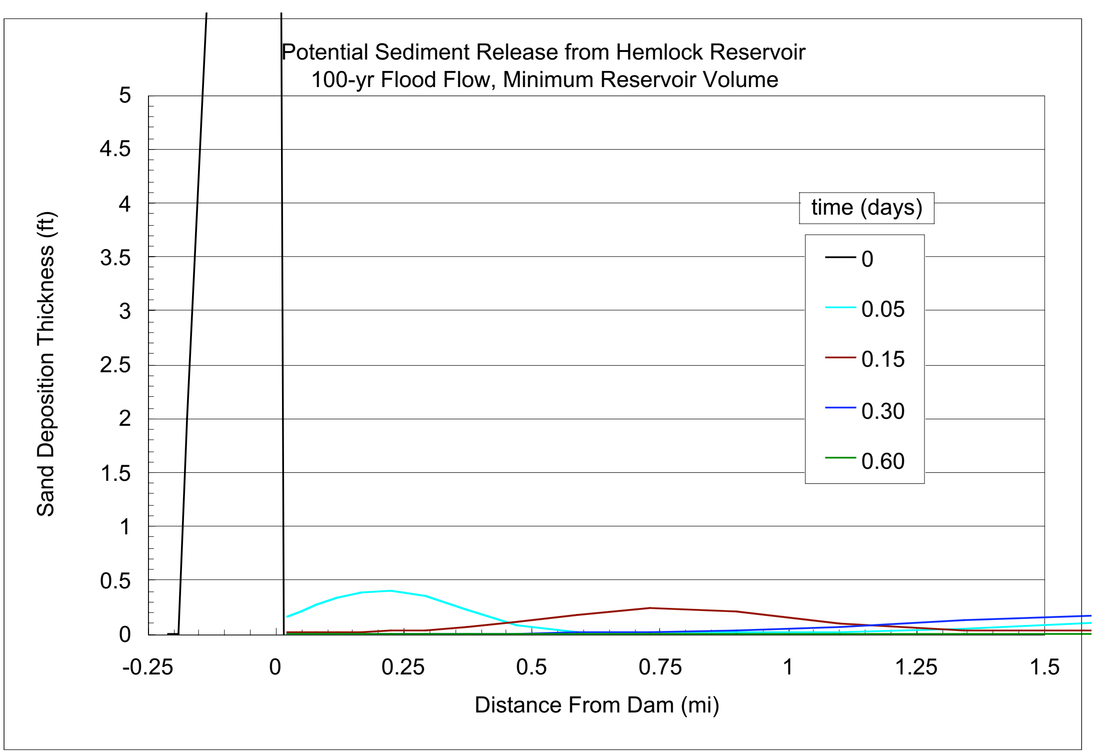

Figure 4-16. Deposition downstream of Hemlock Dam for 100-year flood following dam removal, assuming minimum reservoir volume.

Table 4-14. Fraction of Reservoir Sediments that will be Suspended as a Function of Flow and Location upstream of Dam.

Distance from Dam (ft)	Max Depth of Sediments (ft)	Suspended Fraction		
		20 cfs	2000 cfs	6000 cfs
0	0.0	0.00	0.25	0.25
100	1.3	0.00	0.25	0.25
200	2.7	0.00	0.25	0.25
300	4.0	0.00	0.25	0.25
400	5.3	0.25	0.50	0.50
500	6.7	0.25	0.50	0.50
600	8.0	0.50	0.90	0.90
700	9.3	0.50	0.90	0.90
800	10.7	0.50	0.90	0.90
900	12.0	0.50	0.90	0.90
1000	13.3	0.50	0.90	0.90
1100	14.7	0.50	0.90	0.90
1200	16.0	0.50	0.90	0.90
1300	17.3	0.50	0.90	0.90
1400	18.7	0.50	0.90	0.90
1500	20	0.50	0.90	0.90

Alternative C

Direct, Indirect and Cumulative Effects

Under this Alternative, the dam would be removed, and the channel dredged and constructed to specifications. This would eliminate much of the downstream sediment movement and depositional effects described under Alternative B. Geotechnical work prior to project implementation would help establish the location of bedrock controls, and would guide the channel design. The channel construction would require excavation of between 25,000 to 40,000 cubic yards of material, which would be hauled to a disposal site in the Pacific Crest area of the Nursery fields.

The downstream sediment deposition effects of this Alternative would be minor in comparison to those described under Alternative B. In general, because the channel would be constructed to design, bedload movement through the constructed channel would likely be increased over average conditions during the first year following project implementation, but the effects to downstream reaches in terms of modifying bed configurations would be insignificant. Over time, because increased material would be moved through the reach now occupied by the lake, downstream reaches of Trout Creek and the Wind River would have higher sediment inputs. Some of the larger material would be stored temporarily in these reaches, forming bed, bar, and channel margin deposits, but most of the smaller particles would continue to be routed through the system due to channel grades.

Alternatives D and E

Direct, Indirect and Cumulative Effects

Effects of this Alternative would be the same as those described under Alternative A except for additional sediment storage capacity created in the lake by dredging.

Water Temperature

Existing Condition

In the summer of 2003, the increase in peak water temperature in the Hemlock Lake reach was 1.5°C. The rate of increase over the length of stream through this reach is approximately 3.0°C per river mile of stream, somewhat higher than the adjoining upstream reach, but considerably lower than the maximum rate of heating in the Trout Creek Flats. The rate of heating through the lake is probably limited to some extent by the greater volumes of water there, and the fact that incoming water is already approaching ambient air temperatures.

In addition to the increase in maximum water temperature levels seen through Hemlock Lake, there is also an increase in the minimum daily temperature during summer months, resulting in higher average temperatures, and a reduced range of diurnal temperature fluctuation. Timing of the daily peak in water temperature is also shifted to later in the day at the station just below the lake, due in part to routing complexities within the lake. The combination of these factors leads to a condition in which the maximum difference in water temperature between the upstream and downstream locations is late at night or very early in the morning, when the temperature differential can be as high as 4°C. Figure 4-17 illustrates these effects by comparing hourly water temperatures at the upstream and downstream sites for a one-week period during the summer of 2003.

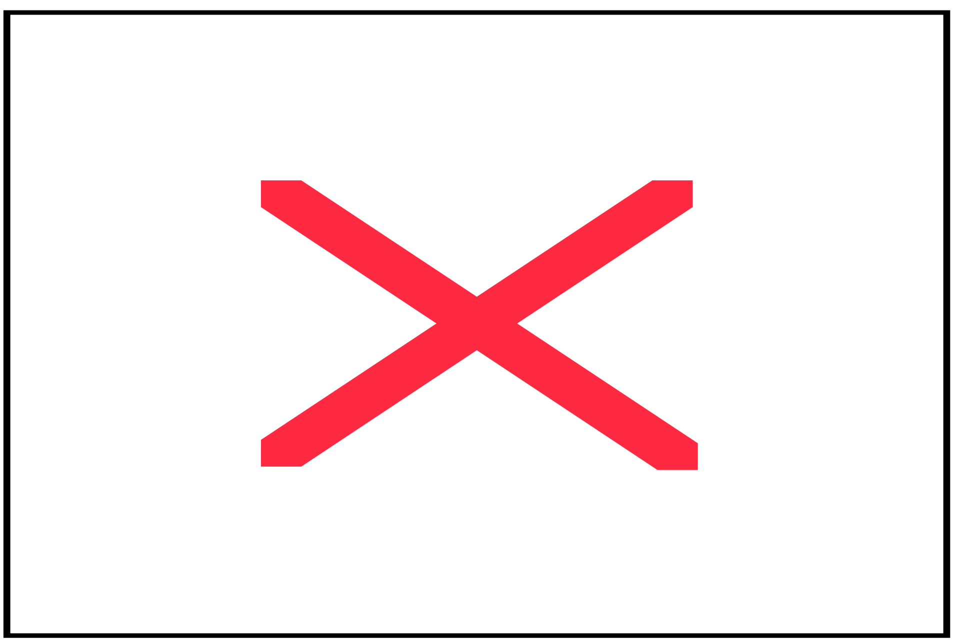

Figure 4-17. Hourly water temperatures in Trout Creek upstream and downstream of Hemlock Lake for the week of August 11-17, 2003.

Daily water temperatures during the week shown average 16.8°C and go through a daily range of approximately 5.0°C at the upstream station. Just downstream of Hemlock Dam, the average daily temperature is 19.0°C, and the range of temperatures is around 3.5°C. As a result of the higher peak and average temperatures in the lake, the frequency and duration at which water in the lake exceeds state water quality standards is also increased. The greater duration of high water temperatures can affect the health of fish and other aquatic organisms living in the water. Figure 4-7 compares temperatures from upstream and downstream of the lake in terms of the number of days that temperatures have exceeded both the state standard of 16°C and two threshold levels of temperature that have significance to salmonids (20°C and 24°C).

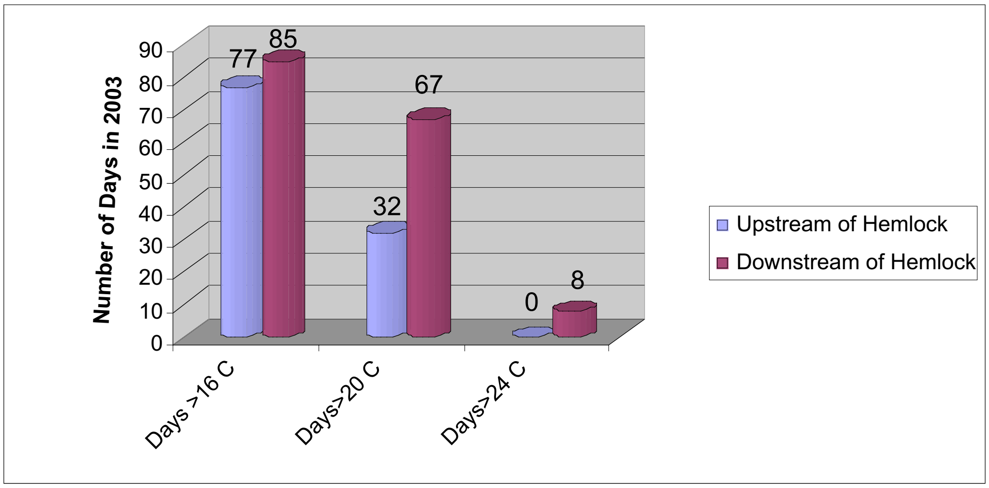

Figure 4-18. Number of days in the summer of 2003 in which water temperatures exceeded threshold levels on Trout Creek upstream and downstream of Hemlock Dam.

Figure 4-7 shows that during the summer of 2003, the dam and lake had little effect on the number of days that water temperature standards were exceeded. This is because throughout much of the summer, water temperatures upstream in Trout Creek were already high. A more significant effect is evident for the really high temperatures. The number of days temperatures exceeded 20°C was over doubled through the lake in this year, and while upstream reaches never reached 24°C, that condition was reached on eight days downstream of the lake.

During the summer of 2003, temperatures in Trout Creek peaked on July 22, at 24.8°C. On that day, water temperatures at the monitoring station just downstream of Hemlock Dam exceeded 24°C for approximately 8 hours, and exceeded 20°C for the entire 24-hour period. For the two-week period surrounding this date (July 19-August 3), water temperatures never dropped below 20°C at the downstream station, while upstream water temperatures dipped below 20°C every night.

Discussion up to this point has focused on conditions thought to represent ambient water temperatures in the stream. Monitoring instrumentation is generally located with the intent of characterizing the "average" condition of the stream or water body. For stream systems that have active flow and are well mixed, this data is often adequate. However, for a system like Hemlock Lake, there is a high degree of variability within the lake in terms of the degree to which water in the lake is mixed with incoming stream flow, movement of water within the lake, and the depth and exposure of water at various points in the lake to solar radiation.

Because of the variability of conditions within the lake, measurements of ambient conditions in the stream flowing out of the lake are inadequate to characterize water temperature conditions across the entire lake. To begin characterizing the range of conditions in the lake, grab samples of water temperature were collected on one afternoon during the summer of 2003, and are being collected several times during the summer of 2004. On July 23, 2003, grab samples of water temperature were collected at five locations within the lake (Figure 4-19). On the day of sampling the maximum water temperature in Trout Creek upstream of Hemlock Lake was 22.9°C, and downstream of Hemlock Lake was 24.4°C.

(Insert photo of the lake with water temperature zones)

Figure 4-19. Grab sample locations for water temperature samples collected on July 23, 2003.

Sampling occurred along the south shore, which receives afternoon shade, and which includes the deepest parts of the lake. Sampling in these areas generally found an average temperature of 23.7°C near the surface of the lake, and 21.7°C near the bottom of the lake. The fact that surface temperatures in the lake were below maximum levels measured just downstream of the lake is probably indicative that the area grab sampled in the lake is the cooler part of the lake due to the shading and depth. The lowest temperature in the lake was found in a deep pool located on the south side of the lake near the bedrock outcrop. This pool was approximately ten feet deep, and had a temperature of 18.3°C at the bottom of the pool. Temperatures found in this pool highlight the importance of both shade and water depth, but may also reflect an area that has relatively little mixing with the main flow of Trout Creek, and/or that may receive localized inputs of groundwater. Follow up temperature work during the summer of 2004 will help to further characterize temperatures across the lake and at depth within the lake.

Alternative A – No Action

Direct, Indirect and Cumulative Effects

Under this alternative, there would be no immediate change to any part of Hemlock Dam or to the lake. Over time, vegetation would continue to develop around the margins of the lake, and sediment would continue to accumulate in the lake and on the delta and bars within the lake. Overall, the depth of the lake would continue to slowly decrease as a result of sediment deposition. Water temperature characteristics of Trout Creek would not change as a result of this alternative being implemented. Peak summertime water temperatures in Trout Creek would continue to exceed the state water quality standards at a relatively high frequency.

Over long time frames, temperatures in the lake may continue to rise slightly as a result of continued buildup of sediment in the lake. However, because the sediment buildup in the lake appears to be occurring at a very slow pace, the rate of change in temperature is expected to be small. Also, as channels in the upper watershed recover from past disturbances, peak water temperatures throughout Trout Creek should begin to decline. This would be a long term, gradual effect, and although it would lead to lower water temperatures throughout Trout Creek, the lake itself would continue to be a source of heating to the waters of lower Trout Creek.

Based on recent monitoring results from Forest Service water quality monitoring stations located upstream and downstream of Hemlock Lake, water entering Hemlock Lake is currently raised by approximately 1.5-2.0°C in the lake during peak temperature conditions. Modeling by the State of Washington (Pelletier, 2002) indicates that the temperature increases within the lake could be as great as 6°C under more extreme flow and weather conditions. With the lake remaining in place, observed increases in temperature can be expected to continue, at greater or lesser levels depending on the dominant flow paths within the lake, and changes in bottom configuration resulting from sediment deposition or scouring associated with higher flows.

Currently, there are a small number of deep pools within the lake that contain cooler water at depth (see Affected Environment section of this report). Over time, it is likely that the depth and areal extent of these few pools within the lake will be diminished as a result of sediment deposition. The rate of this infilling will depend largely on flow paths within the lake and the volume of sediment supplied to the lake. If these pools are reduced in depth or areal extent, the water temperature refugia that they currently provide will also be reduced.

Alternative B

Direct, Indirect and Cumulative Effects

Implementation of this alternative would affect water temperatures both in the immediate vicinity of Hemlock Lake as well as downstream reaches of Trout Creek. The change in temperature would result from reductions in the surface area of exposed water, decreased travel time for water flowing through the area now occupied by the lake, the increased potential for topographic shade on the stream, and changes to flow pathways in the area now occupied by the lake. Peak and average summer temperatures would be reduced from current levels, and the timing of daily peaks may be shifted forward to more closely follow other reaches of Trout Creek. In addition, the range of peak temperatures now found across the lake would likely be reduced. The extent to which any of these occurs will be dependent upon characteristics of the channel that forms through the lake reach, vegetation development along the stream, and weather conditions.

Peak water temperatures in Trout Creek are currently increased by approximately 1.5-2.0°C in the reach now occupied by the lake. If the lake is removed, peak water temperatures will change in this reach of Trout Creek as a result of the transformation of the reservoir to an active stream.

During the period of active channel development and adjustment, there will be little or no vegetative shading on the newly formed streambanks. Water temperatures during this period would continue to increase in the reach through the former lake. During the first few years, the average rate of water temperature increase through the upper portion of the channel would be maintained or possibly increased, as a result of the reduction in volume of water, and the continued exposure to solar radiation. In the lower portion of the channel where the gradient is increased and bank slopes are relatively steep, the stream may receive some level of topographic shading and localized shading from structure within the channel. In addition, because of the increased slope, water will move more rapidly through this reach, and have less exposure to the sun. Through this reach, water temperatures would likely be maintained or possibly show a slight decrease, particularly if hyporrheic return flow or groundwater inputs are captured as the channel incises through lower lake sediments.

Following the period of highly active channel re-establishment, streambanks will be planted with a mix of vegetation to provide erosion control, bank stability, and shade to the stream, and ultimately to form a new riparian forest along the newly re-formed channel. It is likely that the channel would begin to experience some shade from the planted vegetation over a period of 10-20 years after the trees are established. A fully effective riparian canopy would take decades to develop.

Over the long term, the relative increase or decrease in water temperatures in the reach now occupied by the lake can be projected by using the existing temperature characteristics of the reaches immediately upstream and downstream of the lake as analogs. The upstream reach would be used to characterize projected conditions in the new channel in the upper portion of what is now the lake, and the downstream reach would be used to characterize projected conditions in the new channel that forms in the lower portion of what is now the lake. Based on the rate of temperature *increase* currently measured in the reach just upstream of Hemlock Lake, and the rate of temperature *decrease* in the reach just downstream of the dam, peak water temperatures through the reach now occupied by the lake are projected to increase slightly in a downstream direction, even after the dam is removed and fully developed canopies are formed in the riparian area. The extent of heating in this reach would be reduced from current conditions under this Alternative by elimination of the lake.

Assuming that temperature dynamics in the upper 70% of the new channel function similar to the adjacent upstream reach of Trout Creek, and that the lower 30% of the new channel functions similar to the adjacent downstream reach of Trout Creek, the net temperature change through the lake reach would be an increase of approximately 0.4°C during peak temperature conditions.

A one dimensional model (Qual2k) was used to further evaluate the potential changes in water temperature that would occur from dam removal. Comparing modeled water temperatures with and without the dam in place provides another estimate of the degree of increase or decrease to be expected through the lake reach. The Qual2K water quality model (Pelletier and XXX) was used for this purpose. Model runs under the current scenario (i.e. with the dam in place) predict temperature increases of approximately 1.1°C through the lake under average summer temperature conditions. Modeling of temperatures through the same reach in the absence of the dam result in peak water temperature increases of approximately 0.3°C through the reach (Table 4-15).

Table 4-15. Comparison of predicted peak water temperatures in Trout Creek with and without the dam in place.

	Modeled Peak Temperature Upstream of Lake	Modeled Peak Temperature Downstream of Lake	Change in Peak Water Temperature
Current Condition (Alternative A)	21.7°C	22.8°C	+1.1°C
Dam Removal (Alternatives B,C)	21.7°C	22.0°C	+0.3°C

As in the previous discussion, the modeled results indicate a reduction in the amount of heating that would occur in the lake, but that water temperatures through this reach of Trout Creek would continue to climb, even in the absence of the dam.

In addition to limiting the increases in peak temperature that occur through this reach, this Alternative would also affect the range of peak temperatures currently seen through Hemlock Lake. Although the lake currently has the highest water temperatures of any other place in Trout Creek, it also has a few pockets of deeper water wherein water temperatures actually remain lower than surrounding reaches of Trout Creek (see Affected Environment section of this report). The source of the cool water in these pools is undetermined, but likely contributors would be subsurface water inputs, and thermal stratification brought about by reduced levels of mixing with warmer Trout Creek waters.

Under this alternative, the deep pools currently found within the lake may or may not persist once the dam is removed and the new channel is formed. The pilot channel to be constructed under this alternative incorporates some of the deeper pools now found in the lake. However, it is unknown whether these pools would remain as pools, and the extent to which mixing of the water within these pools would be increased as streamflows are directed through them.

Alternative C

Direct, Indirect and Cumulative Effects

This Alternative proposes to remove the dam and to construct a channel through the area now occupied by Hemlock Lake. Sediments removed from the area of the constructed channel would be hauled offsite.

The effects of this Alternative on water temperature would be nearly identical to those described for Alternative B. Under this Alternative the period of time and the significance of channel adjustments following dam removal would be reduced, because the channel would be constructed in a stable configuration and location. As a result, establishment of riparian vegetation and channel shading may begin to occur one to two years earlier than under Alternative B.

Alternatives D and E

Direct, Indirect and Cumulative Effects

This Alternative proposes to leave the dam in place, repair or replace the fish ladder, and to dredge sediments from the lake to increase depth and decrease heating within the lake. The deepening of the lake by dredging would in part be maintained by operation of the sluice gate on an annual basis to move sediments through the system. The sluicing of material would annually re-scour the area around the sluice gate, and maintain some limited area of deeper water toward the lower end of the lake. The upstream extent of this sluicing effect is unknown and probably not large, except that the deepening of the lower portion of the lake would enhance the incremental downstream movement of sediments from the upper reservoir.

In the short term, dredging of the lake would likely improve water temperatures within the lake and in downstream reaches of Trout Creek. Modeling of water temperatures under the current and dredged conditions indicates that maximum temperatures would still increase through the lake following dredging, but the amount of heating would be reduced by approximately 0.9C (Figure 4-20). Based on the modeling results alone, dredging of the lake would have approximately the same effect as removal of the dam in terms of immediate effects to peak water temperatures in the area of the lake. Dredging would also retain and possibly enhance the water temperature refugia currently found in the deeper portions of the lake, although the benefit would be temporary if dredging is not repeated.

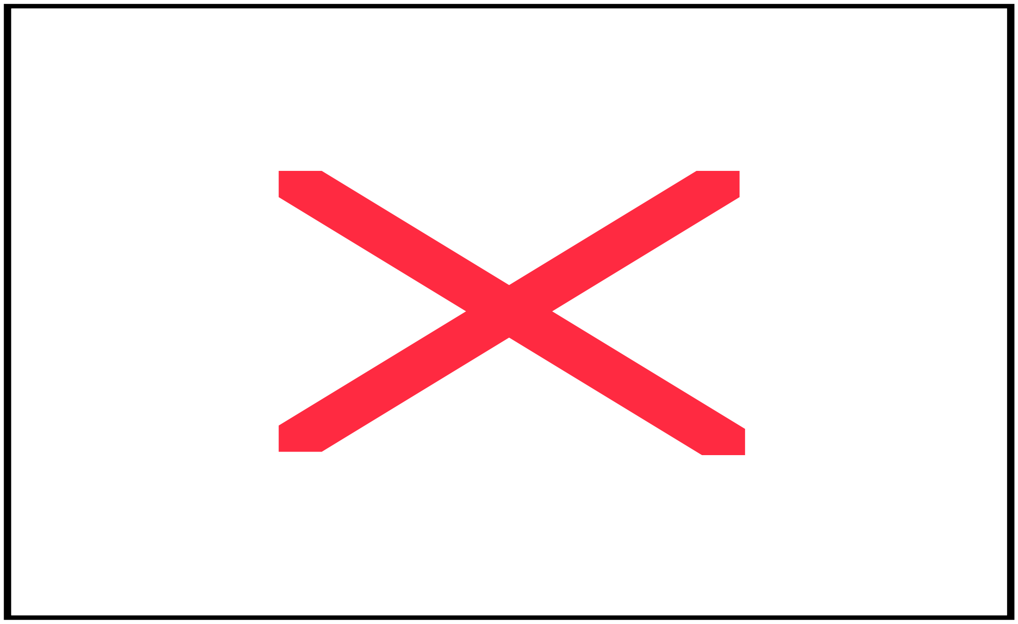

Figure 4-20. Modeled temperature maximums on Trout Creek under Alternative A and Alternatives D and E.

Over longer time periods, the dredging would need to be redone periodically to retain or recapture the temperature benefits of the deepened lake. Figure 4-21 shows the temperature improvement through the lake immediately following dredging, compared against the temperature increase that would occur after approximately one half the dredged excavation refills.

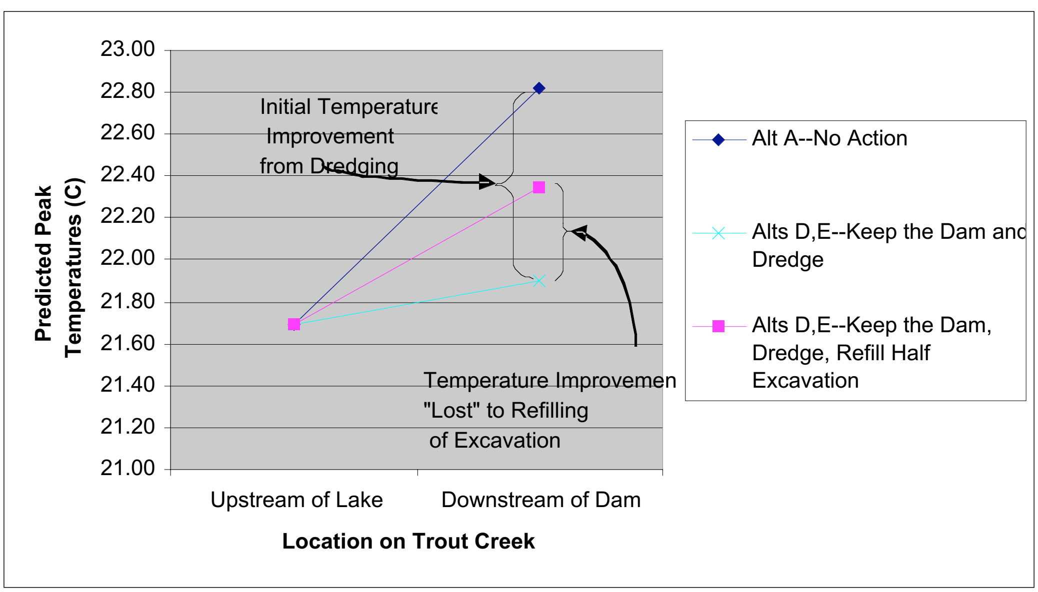

Figure 4-21. Initial improvements in water temperature resulting from dredging, and the amount of improvement that is "lost" when the dredged area of the lake refills by half.

Although regular operation of the sluice gate is expected to help with maintaining depth in the lake, the spatial extent of this effect is not expected to be sufficient to retain the full benefits of dredging. Moreover, dredging the lake will increase the trap efficiency of the dam, so that sand deposition in the lake will increase from current levels. Floods large enough to mobilize the bed would be expected to refill excavations in the channel, so to retain the full benefits of dredging, the lake would need to be dredged after every 5 to 10-year flood (BOR).

Turbidity/Suspended Sediment

Existing Conditions

As elsewhere in the watershed, turbidity levels in Trout Creek in the Hemlock Lake reach are typically correlated with stream discharge levels. Turbidity levels near Hemlock have been measured in …

In addition to the turbidity changes that occur in Trout Creek from upstream processes, turbidity within the lake itself is increased to some degree and within some portions of the lake during summer months as a result of swimming and wading activities. Although no monitoring has been conducted to evaluate the levels of turbidity that occur there, it is likely that most of the turbidity increases occurring within the lake as a result of recreational activities are not translated downstream. This is primarily because of the slow water velocities through the lake, and the distance between the majority of the recreational activities and the dam.

Alternative A—No Action

Direct, Indirect and Cumulative Effects

This Alternative would do nothing to the dam or any of the sediments behind it. Turbidity and suspended sediment levels in Trout Creek would not be changed by implementation of this Alternative. The dam would continue to function as a sediment trap, but because of the existing levels of sediment in the lake, the efficiency of the dam in trapping sediment is low. Continued infilling of the reservoir would slowly cause increased amounts of material to be routed over the dam, but because the lake is already near equilibrium conditions (i.e. sands and finer sediments coming into the reservoir are largely being routed through), this will be a very long, slow process.

Over time, Lower Trout Creek and the Wind River will continue to receive increased sediments as a result of the increasingly poor trap efficiency of the dam. Because lower Trout Creek and the Wind River are sediment supply-limited, the effects in terms of turbidity and suspended sediment levels will be of relatively short duration. Suspended sediments in these channels will be rapidly routed downstream toward the mouth of the Wind River.

Alternative B

Direct, Indirect and Cumulative Effects

Under this Alternative, sediments will be allowed to erode naturally from the reservoir area. Before the dam is removed, the sluice gate will be opened and sediments will be eroded from the reservoir and travel downstream. Suspended sediment concentrations will be extremely high in lower Trout Creek and the downstream reaches of the Wind River during the initial flushing of sediments, and during subsequent and increasingly higher flows. It is assumed that the sluicing will be performed during the low flows of August, when the average flow is slightly less than 20 cfs. BOR:

> Immediately after the sluiceway is opened, suspended sediment concentrations downstream of the dam will increase. At an assumed discharge of 20 cfs (August low flow), suspended sediment concentrations are expected to stabilize

downstream at approximately 5,000 mg/L, and this condition would persist for 20 to 40 days (BOR).

Once flows in Trout Creek increase, additional sediment will be eroded from the lake. At 200 cfs, the sediment concentrations downstream of the dam would be slightly higher, but last only 3 to 4 days. At 2000 cfs, the high sediment concentrations will last no more than one day. After this initial high concentration period is over, the sediment concentrations will return to background levels for subsequent flows. (Blair will provide a table of concentrations at various flow levels)

Sediment concentrations in the Wind River will be much lower due to the dilution of Trout Creek flows. During the month of September, the average streamflow downstream of the confluence of the Wind River and Trout Creek is approximately 6 times that of the flow in Trout Creek alone. Because the concentrations in the Wind River at this time of year are expected to be essentially zero, the concentrations in the Wind River downstream of the confluence with Trout Creek would be approximately 1/6 of the concentrations in Trout Creek. Therefore, for a period of 20 to 40 days following removal, the concentrations will be approximately 800 mg/L. At the mouth of the Wind River, the concentrations will be further reduced because of the additional flow there. The flow at the mouth of the Wind River during the month of September is approximately 10 times that in Trout Creek. Therefore the concentrations would be approximately 500 mg/L at the mouth of the Wind River for a period of up to 40 days.

Alternative C

Direct, Indirect and Cumulative Effects

Under this Alternative, the dam would be removed and a channel constructed through the area now occupied by the lake. During construction, Trout Creek flows would be piped past the work area to minimize turbidity occurring during construction. Because under this Alternative, the channel would be constructed to its final form, grade and location, the extent and duration of channel adjustments following construction work would be much lower than under Alternative B. As a result, this Alternative would generate much lower levels of fine sediment, and the duration of turbidity increases would be lower than under Alternative B.

Expected increases in turbidity under this Alternative would occur following rewatering of the constructed channel. Turbidity levels immediately downstream of the Hemlock Dam site would be expected to be elevated by several hundred NTU's or more for a short period following rewatering of the constructed channel. The turbidity spike would occur over a period of hours, before returning to near pre-project levels. During each successively higher flood following construction, turbidity levels would again be elevated—particularly on the rising limb of the storm hydrograph. Once the flood peak passed, turbidity levels would again approach background levels.

Due to the high gradients in Trout Creek and the Wind River downstream of the dam, only minor attenuation of turbidity levels is expected downstream, except that which occurs as a result of dilution when Trout Creek meets the Wind River, and when subsequent tributaries enter the Wind River. As described under Alternative B, the dilution effect of the Wind River and other downstream tributaries could reduce suspended sediment concentrations near the mouth of the Wind River to approximately 1/10th the levels found in Trout Creek below the dam.

Alternatives D and E

Direct, Indirect and Cumulative Effects

This Alternative would leave the dam in place but dredge much of the reservoir. The fish ladder would also be reconstructed. During the dredging activities, Trout Creek flows would be piped past the work area to minimize direct effects of construction on water quality. Following dredging and dam upgrades, operation of the sluice gate would be re-initiated during winter months, to coincide sluicing with high streamflows.

In the near term, turbidity levels under this Alternative would be far lower in magnitude and of lower duration than for either Alternative B or C. Turbidity levels would increase under this Alternative primarily during during construction of the fish ladder and establishment of the bypass flows of Trout Creek. The turbidity increases would result from blasting and construction associated with the fish ladder construction, and also from construction of the coffer dam at the upstream end of the lake, installation of the culvert to carry Trout Creek flows, and any incidental disturbance associated with the bypass.

During the actual dredging, the main flow of Trout Creek would not be in the work area, so the only turbid water would be that water that is encountered during excavation. The dam would be used as a temporary settling pond for this water, and the embayment on the south side of the lake would also be available as a settling area for water pumped out of the excavation. As a result of these measures, turbidity levels during construction would be relatively low.

Once Trout Creek flows are returned to the lake, there will be a brief increase in turbidity downstream as any entrained sediments that are not redeposited within the lake are routed downstream. The magnitude and duration of this turbidity pulse is likely to be small and of short duration.

During winter months, turbidity levels downstream of the dam would be increased as a result of the re-establishment of sluicing. The degree of increase in turibidity is not known. However, because the sluicing would be timed to coincide with periods of high flow and high turbidity levels in Trout Creek, the proportional increase in turbidity levels caused by sluicing would be somewhat reduced.

Longer term effects of this Alternative on turbidity levels would be similar to those described under Alternative A, except that the result of dredging the lake would increase the trap efficiency of the dam, so downstream turbidity levels may decrease slightly during non-sluicing periods and during the period of time when the extra depth in the lake is retained. As described elsewhere in this report, the full benefit of dredging in terms of deepening the lake would only last for a limited period of time, so any improvement in turbidity that occurred as a result of the increased trap efficiency of the dam would be minor and relatively short-lived, coinciding with the persistence of the increased lake depths.